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A MULTIPURPOSE SATELLITE EJECTION SYSTEM

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ABSTRACT

A design is presented for a pneumatic ejection system capable of ejecting a spin stabilized satellite from the cargo bay of the space shuttle vehicle or other space vehicles. This system was originally designed for use on the Spacelab 6 shuttle mission, but is now being considered for use with expendable rockets for launching satellites. The ejection system was designed to launch a 150-lb satellite at an initial ejection velocity of 32 ft per second with a spin rate of 30 revolutions per minute.

The ejection system consists of a pneumatic cylinder, satellite retaining mechanism, and bearing assembly to allow the satellite to rotate during the spin-up phase. As the cylinder is pressurized rapidly causing movement of the actuation piston, the mechanism automatically releases the spinning satellite by retracting a pneumatic locking pin and three spring-loaded holddown pins. When the piston reaches the end of its stroke, it encounters a crushable aluminum honeycomb shock absorber which decelerates the piston and retaining mechanism. The assembly is designed for multiple uses except for the crushable shock absorber and pyrotechnic valves.

The advantage of the design is that it has the ability to meet a variety of ejection requirements by varying the pressurization rate of the pneumatic cylinder and the speed of the direct current spin motor, thus giving the system a high degree of flexibility and versatility. This device was awarded U.S. Patent No. 4554905 on November 11, 1985.

BACKGROUND INFORMATION

This multipurpose satellite ejection system (MPSES) was initially conceived to eject a series of flight experiments in formation from the shuttle cargo bay. The experiment, the magnetospheric multiprobe (MMP), was proposed for observations of the Sun's vector magnetic fields. Figure 1 shows the MMP satellite cluster that was to be mounted in the orbiter payload bay.

OVERALL DESIGN

This mechanism was designed to launch satellites from the orbiter cargo bay with some pre-determined translational acceleration and rotational velocity, which can be varied with different mission requirements. Translational acceleration is accomplished by the pneumatic piston system shown in Figure 2, which shows a preliminary flight configuration. Figure 3 shows a test configuration. A pneumatic system was chosen over a simpler spring system for the aforementioned capability to vary the translational acceleration for

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different missions, and for safety and damping considerations. The piston is hollow on the gas side for an accumulator effect, damping out the shock effect created by the sudden entrance of gas into the cylinder at the beginning of the ejection sequence. Rotational velocity is accomplished by rotating the satellite and its cradle with a spin motor (Fig. 3). The satellite is retained on the cradle by three spring-loaded retaining pins, which rotate with the cradle inside a retainer cup, and are deactivated near the beginning of the piston stroke. Figure 4 shows the interface where these elements are located. The spin motor drives a pinion gear, which in turn drives an inner ring gear attached to the cradle. The momentum of the piston after ejection is absorbed by a honeycomb shock absorber (Fig. 2), which is crushed by the impact of the piston. The honeycomb shock absorber can be removed at the end of the mission and replaced with a new one in preparation for another mission.

Support hardware includes a pneumatic locking pin for cradle retention (Fig. 2); spin motor support structure (Fig. 3 shows the correct orientation); tripod struts for pneumatic cylinder support (Fig. 2); a universal joint (rod end clevis, Fig. 2) as a support base for the pneumatic cylinder; a hold down latch (Fig. 2) for satellite retention during launch; and the MPSES support structure. The rod end clevis allows the cylinder, and thus the satellite, to be mechanically aligned with the orbiter by manipulation of turnbuckles on the tripod struts. Additionally, a spring-loaded retaining latch is located on the cylinder to retain the piston at the top of its stroke after satellite ejection (Fig. 2). The MPSES support structure, which is for support of the MPSES during launch and landing and prevention of hardware contamination, is shown in Figure 2.

The indexing pin (Fig. 2) is a pyrotechnically actuated mechanism that stops the cradle/satellite from rotating if the ejection is aborted due to some mechanism failure after the hold down latch is unlatched and the spin motor is started.

EJECTION SEQUENCE

A central controller (not shown in figures) located on the system hardware will command the sequencing. The controller will be initiated by commands from the crew cabin. The pneumatic system pressure sphere (see Fig. 2) will be pressurized through the fill line. After the spin motor is started, the pyrotechnically actuated valve is opened, allowing pressurization of the pneumatic locking pin and the pneumatic cylinder. The gas line running from the pyrotechnically actuated valve to the pneumatic locking pin is sized so that the locking pin is unlocked before the piston begins acceleration. Releasing the locking pin frees the pneumatic piston, the cradle, and the satellite for ejection. As the piston moves upwards, it allows the spring-loaded retaining pins to release when they clear the retainer cup, then accelerates the satellite out of the cargo bay. The satellite is held on the cradle by acceleration loads, until the piston reaches the end of its stroke. At this point, the spring-loaded retaining latch locks the piston, preventing it from freely moving and damaging itself.

ANALYSIS

A mathematical model of the pneumatic system was developed to predict the g-force created by the ejection system on the experiment. The model incorporates the following variables: system weight (including satellite), design separation velocity, gas constant, specific heat ratio, and absolute gas temperature, sphere volume, sphere pressure, cylinder inlet line diameter, initial cylinder volume, cylinder diameter, vent orifice area, and piston stroke. The model yielded these parameters: stroke time, percent stroke, cylinder pressure, ejection acceleration, and ejection velocity. Figures 5 through 8 show the latter four parameters as functions of time.

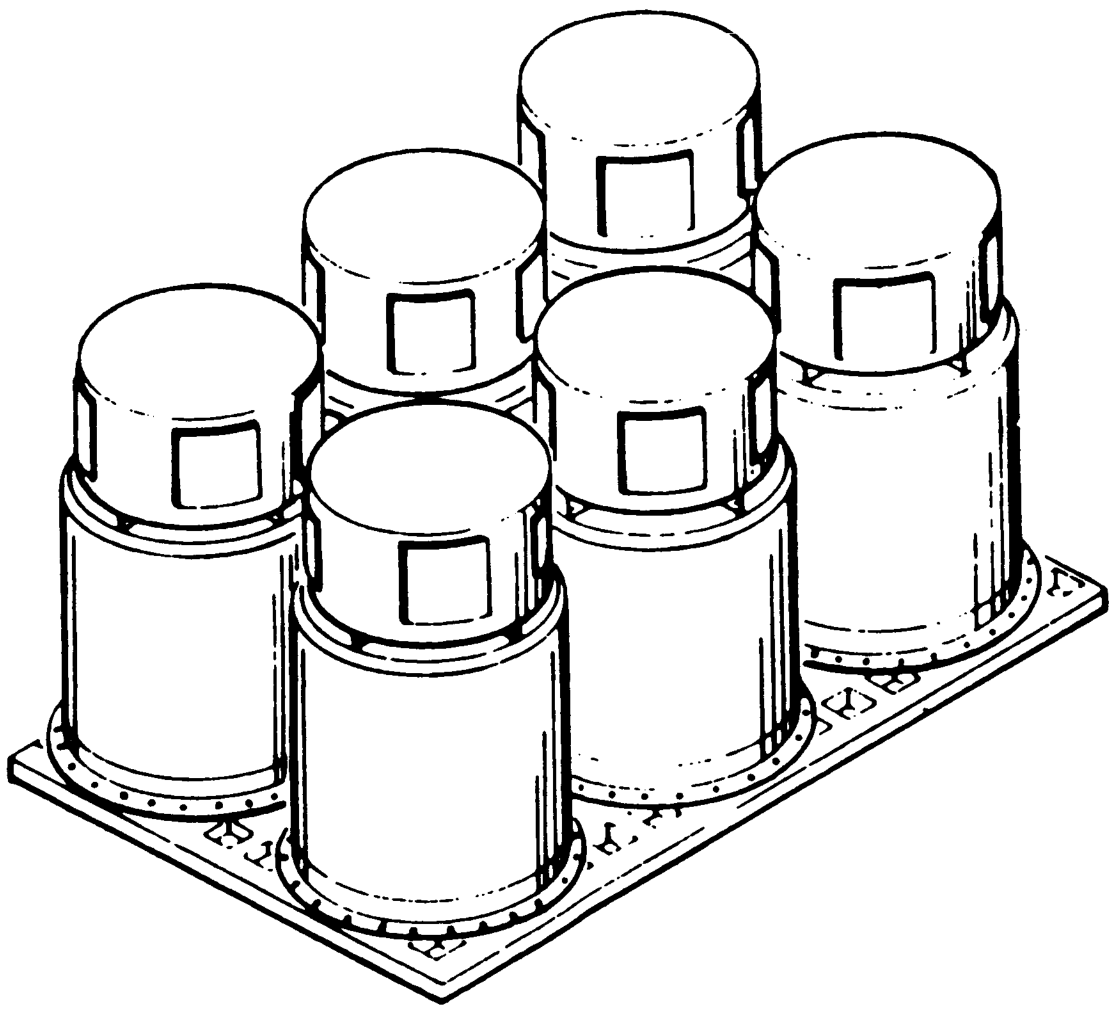

Figure 1. MMP Satellite Cluster.

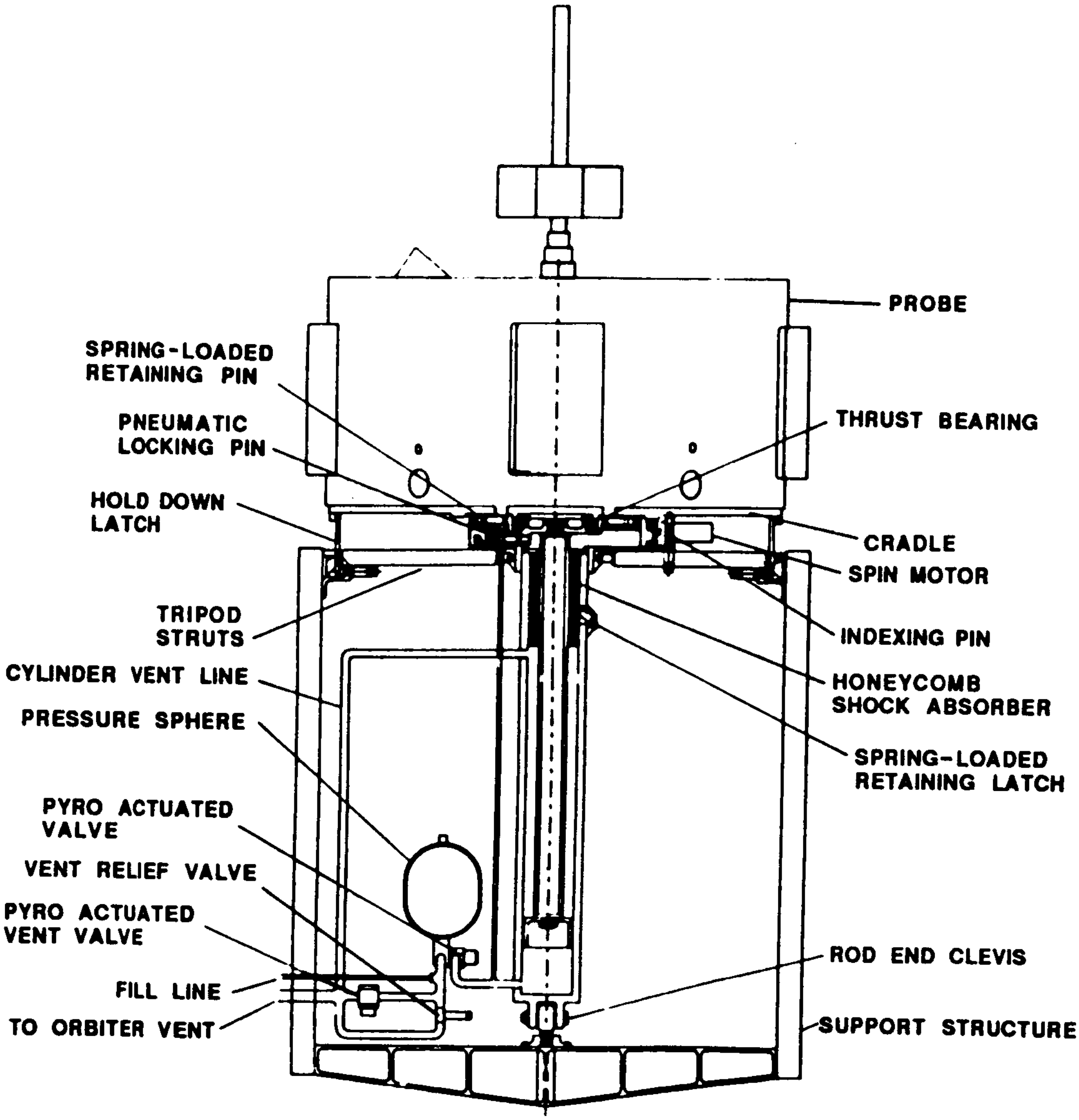

Figure 2. MPSES Flight Configuration.

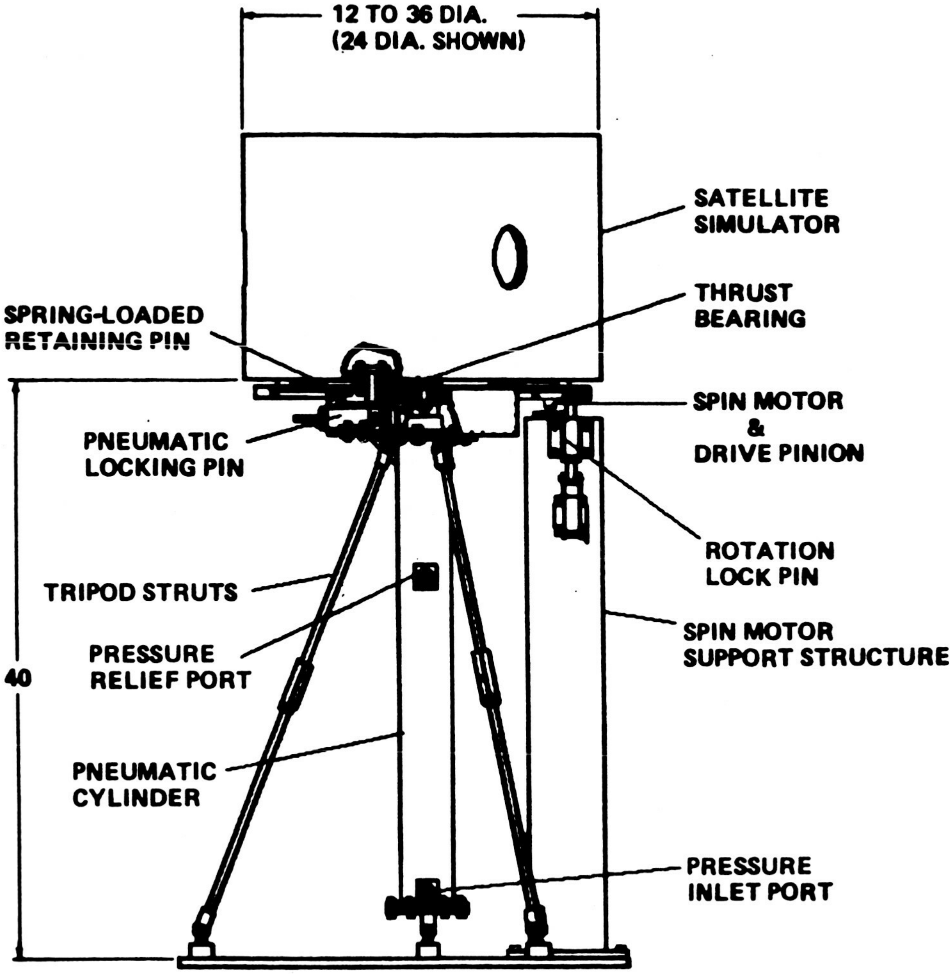

Figure 3. MPSES Test Configuration.

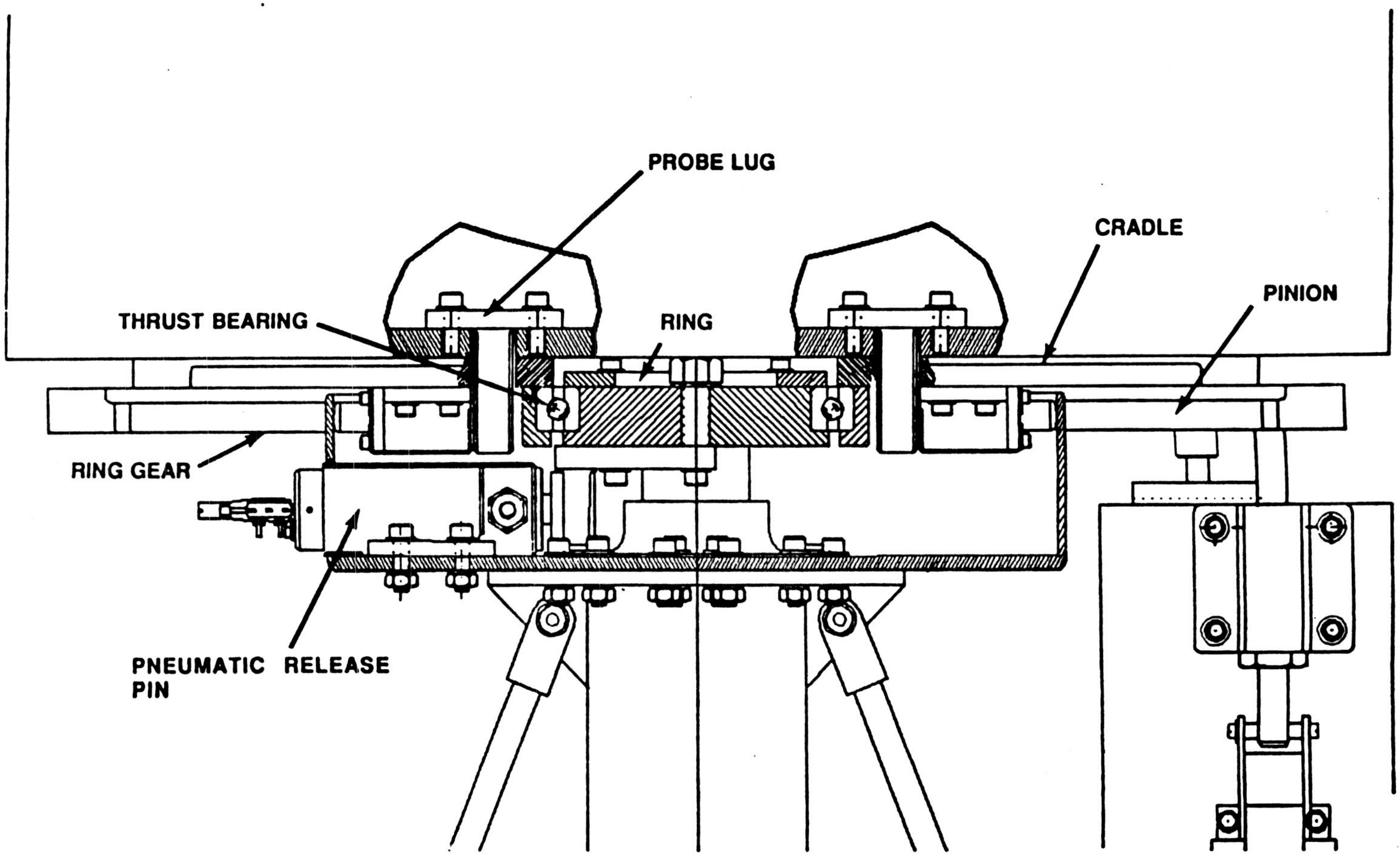

Figure 4. Critical Interface of MPSES Test Configuration.

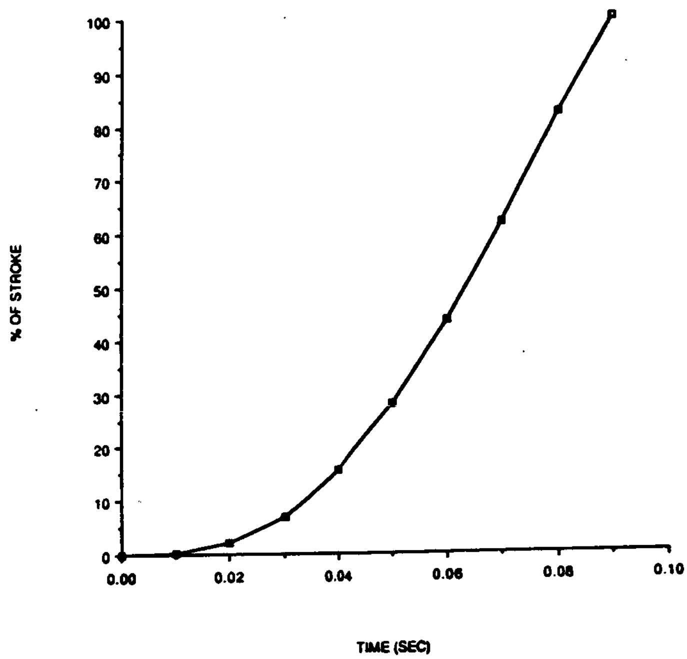

Figure 5. Percent of Stroke Versus Time.

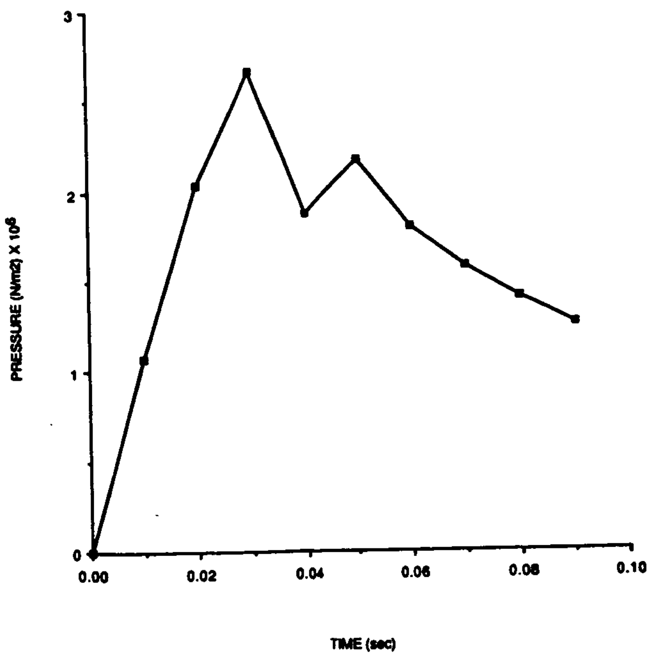

Figure 6. Cylinder Pressure Versus Time.

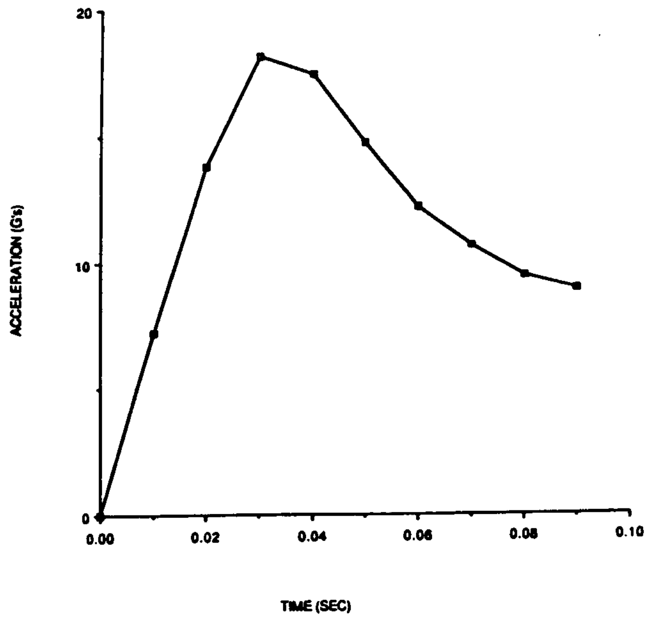

Figure 7. Acceleration Versus Time.

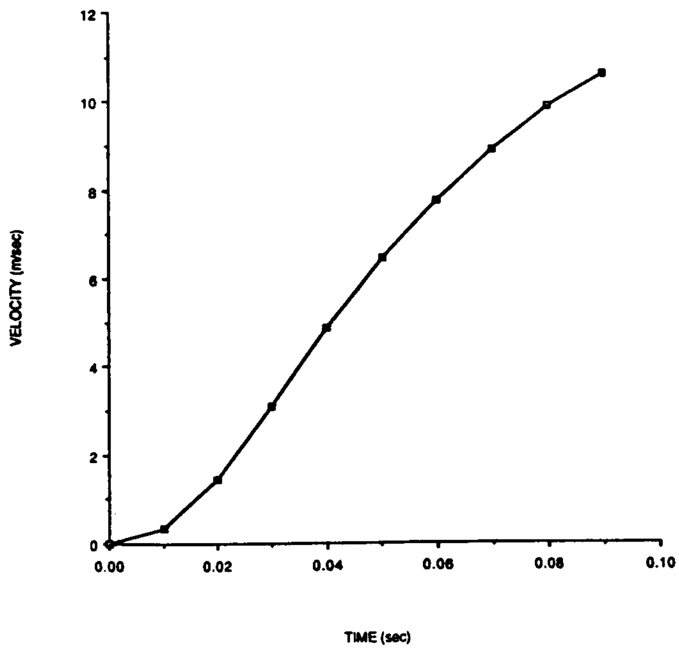

Figure 8. Ejection Velocity Versus Time.